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THE DISTRIBUTION OF THUNDERSTORMS IN THE UNITED STATES, 1904–33

By WILLIAM H. ALEXANDER

[Weather Bureau, Columbus, Ohio, Dec. 10, 1934

This is the third and in all probability the last paper on the above topic by this writer. The first was published in the MONTHLY WEATHER REVIEW, July 1915, **43**:322–340, and covered the 10-year period 1904–13; the second was published in the July 1924 issue of the REVIEW, **52**:337–343, and covered the 20-year period 1904–23. The reader is referred to the first of these papers for a general introductory statement to the discussion, and for a rather comprehensive account of the methods or rules used by both the Weather Bureau and its predecessor, the Signal Service, in recording thunderstorms, prepared by C. F. Talman, librarian of the Weather Bureau in Washington, D. C. The lines on the charts are in some cases slightly smoothed; and lines are not always drawn around single isolated values. *On the June chart, the value 378 at Macon, Georgia, should be 318.* As a 30-year record probably affords a safe and reliable basis for these charts, perhaps a few observations regarding them will not be out of place.

In the first paper, the discussion of the monthly charts was begun with that for December, for the reason that December seemed to have fewer thunderstorms than any other month; but the 30-year record seems to prove this statement erroneous, and so we now begin with the January chart (fig. 1). The January 30-year chart, as in the case of the 20-year chart, shows the center of thunderstorm activity for that month to be over northern Louisiana; there is also considerable activity in all the Gulf States and in the South Atlantic States as far north as the Carolinas, and in the Mississippi Valley States northward to and including Missouri and the lower Ohio and Tennessee Valleys. While the western half of the country is relatively free from thunderstorms during the month of January, there is a rather significant isoceraunic [1] over northern Utah.

Turning our attention to the February chart (fig.2), we note a very considerable increase in thunderstorm activity in all the Gulf States and in the Ohio and Tennessee Valleys and northward to the Lake region, and the center of this increased activity has shifted a little east and is apparently centered over Mississippi, southern Alabama and extreme western Florida. The western secondary, still quite weak, now appears over southern Arizona.

Figure 3 seems conclusively to establish the fact that the center of greatest thunderstorm activity during the month of March is over southern Arkansas, west-central Mississippi and extreme northeastern Louisiana, and not over Kentucky and Tennessee as indicated by the chart based on a 10-year record. The area of increasing thunderstorm activity has continued to spread rather rapidly north and east, and now includes practically the entire eastern half of the country. There has also been an increase over the Southwest, notably in Arizona, New Mexico, and Utah.

During the month of April (fig. 4) we see a slight westward shift of the center of greatest thunderstorm activity, and northeast Texas is now included along with northern Louisiana and Arkansas. Practically no part of the United States is entirely immune from these storms in the month of April though they are quite rare along the Pacific coast; and activity is becoming notably pronounced in the southern Rocky Mountain States.

The May chart (fig. 5) reveals at least one very interesting and significant development, apparently not foreshadowed on any of the preceding charts, namely, the sudden appearance of a very definite secondary center of activity on the west Florida coast in the vicinity of Tampa. The primary center is now showing a tendency to move or spread northward into Missouri and northeastward into the Ohio and Tennessee Valleys. The active center for the western half of the country is still over the southern Rocky Mountain States, and thunderstorm activity has increased generally over the country.

The most obvious fact revealed by the June chart (fig. 6), perhaps, is that thunderstorms are now general and rather frequent over all eastern and central districts, including some of the Rocky Mountain States; and the most interesting fact is that the Florida center of activity has now become the *primary* center and includes several of the Southeastern States, while the secondary center is apparently over Colorado. In the area of greatest activity, thunderstorms occur on the average about every other day, and in the secondary area, about every third day.

We now come to the month of maximum thunderstorm activity, namely, July (fig. 7). The outstanding feature of this month is the marked increase in thunderstorm activity over the Rocky Mountain States; the secondary over the Southwest has about the same intensity as the primary over the Southeast, the latter recording a total

[1] The following terminological note by C. F. Talman is reprinted from the Monthly Weather Review, July 1924, 52: 337. In 1879 W. von Bezold and C. Lang applied the name "isobront" to a line drawn on a chart connecting places at which the first thunder in a thunderstorm was heard simultaneously. The word has since become fully established in meteorological literature with a somewhat broadened meaning, being applied generically to thunderstorm isochrones, including those of first thunder, loudest thunder, beginning of rain in a thunderstorm, etc. A chart of isobronts shows the progress of a particular thunderstorm across the country.

To avoid confusion, some different name should be applied to lines of *equal thunderstorm frequency*, such as appear on Mr. Alexander's charts and on charts of similar character that have been drawn for other countries and for the world at large. It is suggested that the isogram of thunderstorm frequency be called an "isoceraunic line", or, briefly, an "isoceraunic" (also spelled "isokeraunic"). "Isobront" and "isoceraunic" are formed from familiar Greek words, the former meaning literally "equal thunder" and the latter "equal thunder and lightning."

of 655 days with thunderstorms in the 30 years, and the former 641. The number of days with thunderstorms has increased along the Mexican border, but the Pacific coast is still practically immune.

During the 7 months, January to July, inclusive, thunderstorm activity has been *increasing* both as to intensity and area covered. In August (fig. 8) we detect the first evidence of disintegration, as shown in the (as yet slightly) diminishing number of thunderstorm days along the Canadian border, and in the weakening of the secondary over the Southwest. However, the average is still high over the southern half of the country; the Pacific coast is nearly free from these phenomena, especially the northern California coast.

The most obvious fact revealed by the September chart (fig. 9) is that thunderstorm activity is rapidly diminishing over the entire country, unless it be along the Pacific coast where there seems to be a very slight increase. The two centers of activity, the primary over Florida and the secondary over northern New Mexico, still persist but both are now weakening rapidly; in fact, a strong secondary is now forming over the middle Mississippi Valley. There is little thunderstorm activity in September along or north of the Canadian border.

In October (fig. 10), the primary center that has been over Tampa for so long seems to have dropped south and is now over Key West, and the secondary is over the Arkansas-Oklahoma border, while a remnant of the erstwhile active secondary over New Mexico persists; but there has been a marked slowing-up of thunderstorm activity generally over the country, the storms being relatively most frequent in Florida and the southern Plains and lower Mississippi Valley States.

As is to be expected, the November chart (fig. 11) shows a still further diminution in thunderstorm activity and in the area covered; in fact the thunderstorm is now relatively rare in all parts of the country, the region of greatest frequency being the Ohio and lower Mississippi Valleys. Both the Florida and the southwest centers have practically disappeared, and the interior portions of the Atlantic States from Georgia to Maine are now almost immune.

The December chart (fig. 12) again reveals the center of greatest thunderstorm activity over northern Louisiana, and very little activity outside of the lower Ohio, lower Mississippi and the Gulf States.

This brings us to the conclusion of the whole matter, namely, a consideration of the annual chart (fig. 13). This chart shows the total number of days with thunderstorms at a large number of stations for the past 30 years (1904–33); it brings out very conspicuously the two great centers of activity, one over Tampa, Fla., and the other over Santa Fe, N. Mex. It is interesting to note that the average number of days with thunderstorms at Tampa is exactly the same, 94, for the 20-year and the 30-year records; the average at Santa Fe for the 20-year record was 73 and for the 30-year record 72; these facts substantiate somewhat the statement in the concluding sentence of the first paragraph of this article, namely, that these charts give *trustworthy* averages. One lesson to be drawn from the annual chart is that no part of the United States is entirely free from thunderstorms. The fact that the topography of Tampa differs so materially from that of Santa Fe introduces some interesting considerations. Tampa is at sea level and Santa Fe 7,013 feet above sea level.

In conclusion, the writer wishes to thank the Chief of the Weather Bureau for permission to gather the data for this paper, and the numerous officials in charge of the stations for supplying them. Through the courtesy of the Meteorological Service of Canada, data from Canadian stations near the border have been used in the present paper.

THE PENNSYLVANIA FIREBALL OF FEBRUARY 27, 1935

By CHARLES P. OLIVIER

[Flower Observatory, Upper Darby, Pennsylvania, May 1935]

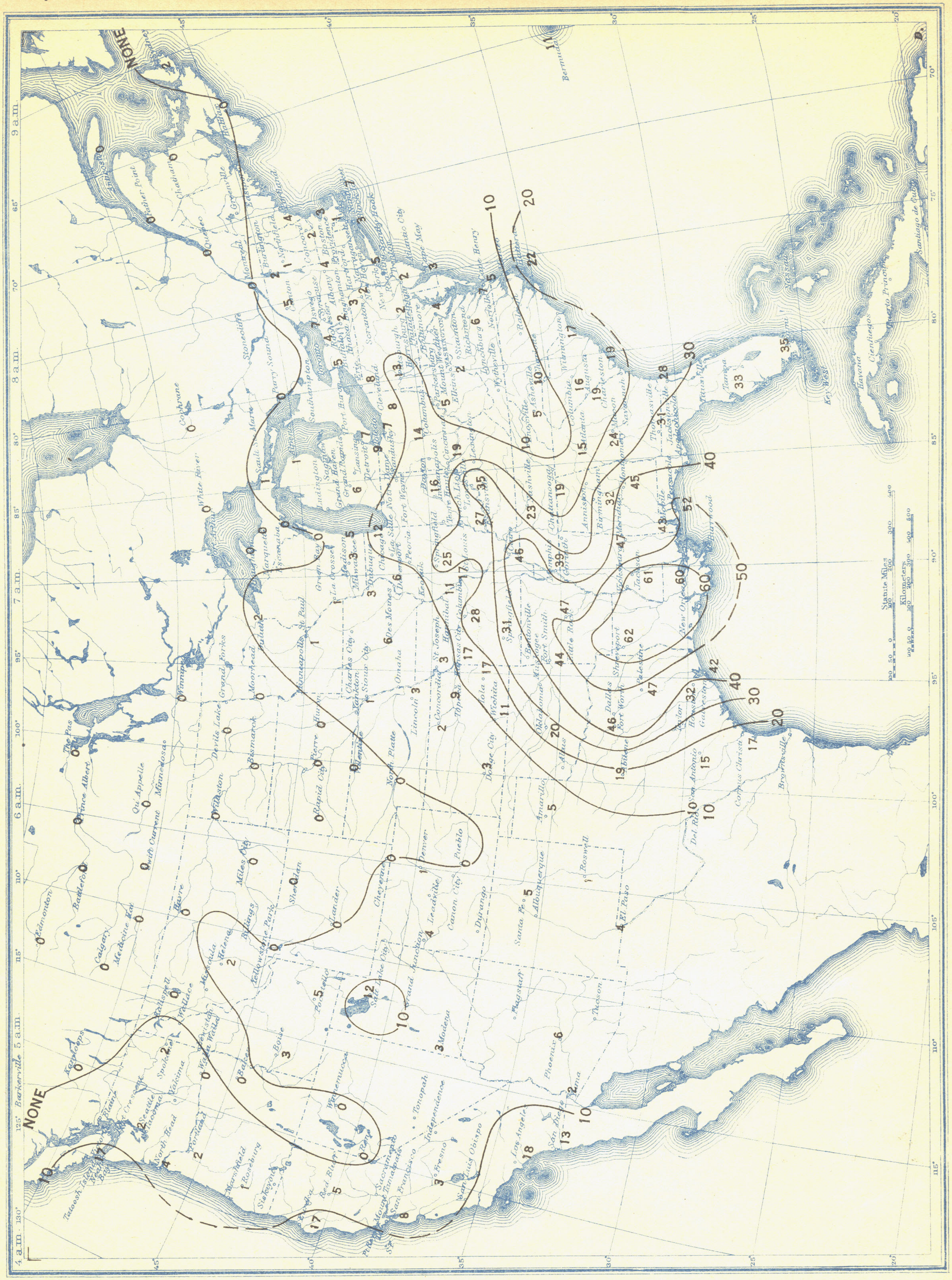
At 6:20 p. m., eastern standard time, February 27, 1935, a fine fireball was seen to fall over Pennsylvania. Efforts to obtain reports of observations were at once made through the newspapers and otherwise. As the body appeared while twilight was still too bright for stars to be visible, good positions were reported only because the planet Venus was in the same part of the sky as seen from eastern Pennsylvania in general. The phenomenon attracted further attention because of the long-enduring train which was left.

In all, 16 observations were reported, as given in table 1. All 16 were concentrated in the sector from northeast to east of the path of the object. It was unfortunately impossible to get any reports from south, west, or north, though the fireball must have been visible from those directions. Seven of the observations received were available for the determination of the height of the upper end of the train, and five for the lower end. It is probable that the body itself was visible considerably higher, but all the observations obviously refer to the upper end of the train.

TABLE 1

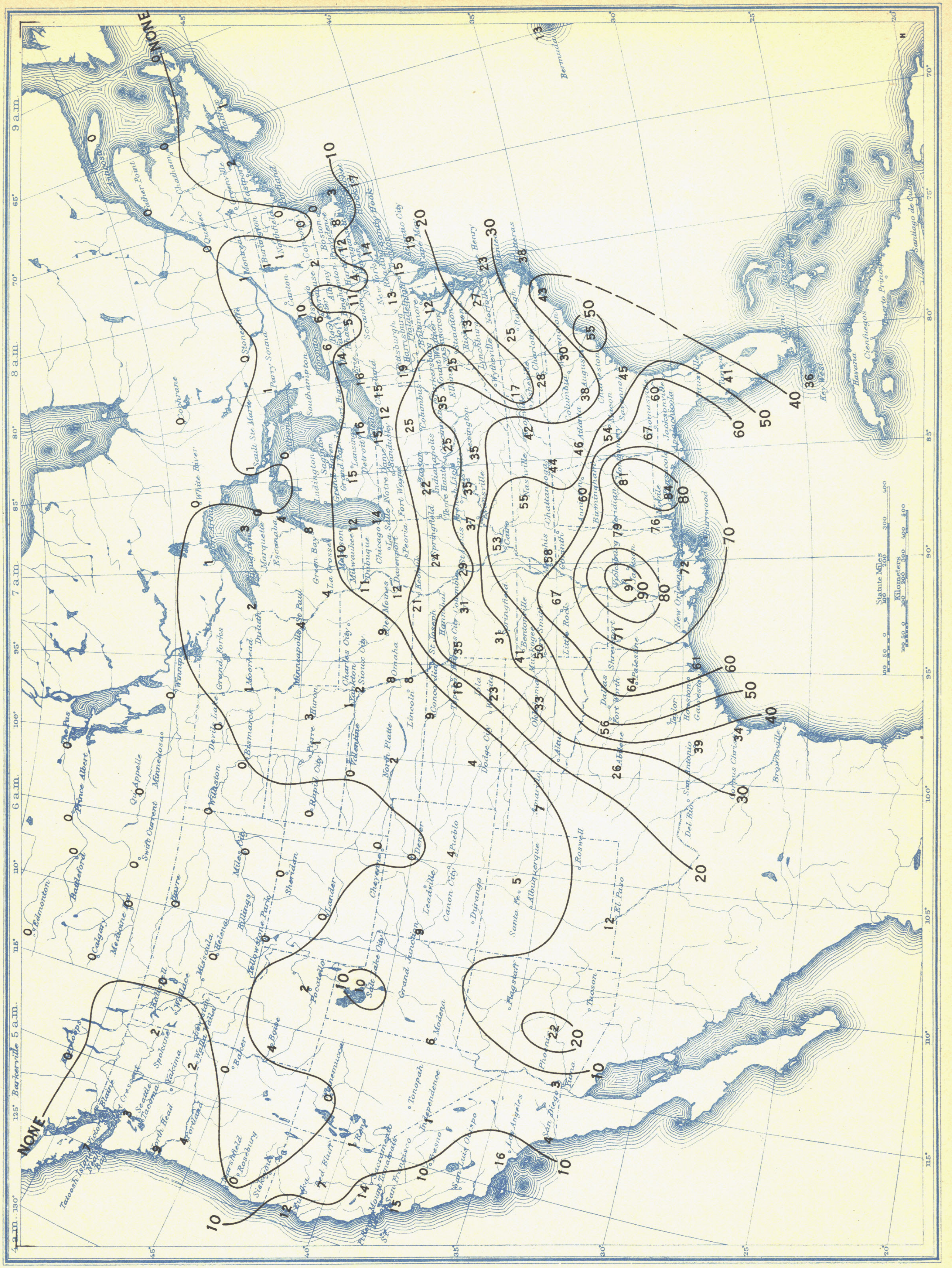
No.	Station	Observer	Color	Duration (seconds)	Duration of train (minutes)
1	Glenolden, Pa	F. W. Smith	Y-W	1±	12
2	Pottsville, Pa	J. D. Smith	Y		4
3	Philadelphia, Pa	W. R. Brown		1−	15
4	Philadelphia, Pa	F. F. James		1−	2+
5	Devon, Pa	E. A. Skilton			
6	Philadelphia, Pa	E. Udell		<6	10
7	Allentown, Pa	C. H. Hoffman	Y		5
8	Magnolia, N. J	Mrs. E. J. Schmidt			
9	Glenside, Pa	Mrs. H. P. Camden			2+
10	Philadelphia, Pa	N. Mendelsohn			
11	Wynnewood, Pa	Mrs. Rose E. McCarthy			12
12	Paoli, Pa	J. B. Patton			
13	Reading, Pa	H. E. Hathaway	B-R-Y	1+	9+
14	Reading, Pa	S. Lash	Y	1−	5+
15	Mehoopany, Pa	W. R. English	Y-R	<5	20-25
16	Rutherford, N. J	W. F. Miner	O-Y	2	8

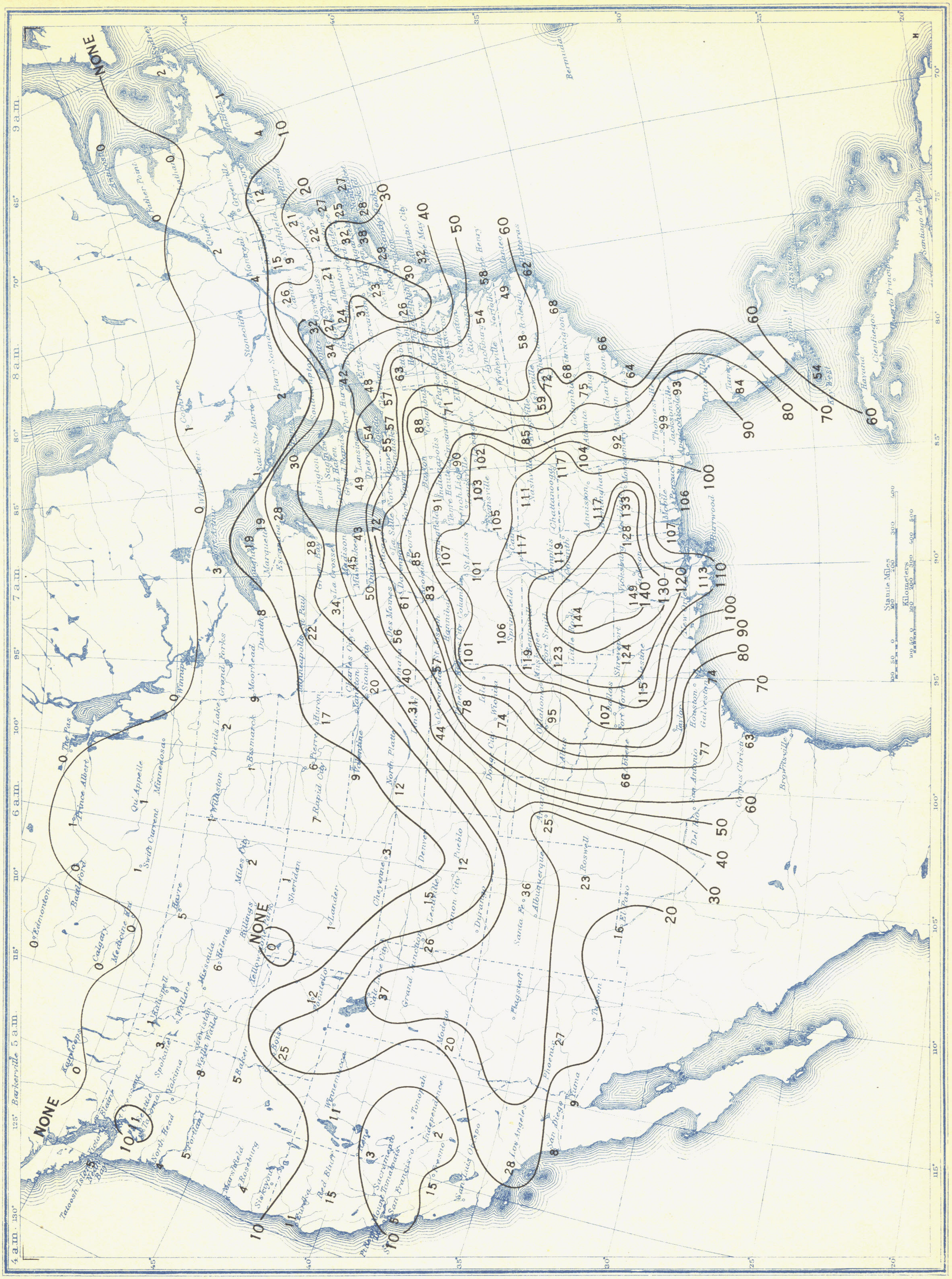
The data given in table 2 were calculated from the observations. As Venus was most fortunately at the right altitude as well as the right azimuth, to serve as a reference point, we may have confidence in the geo-



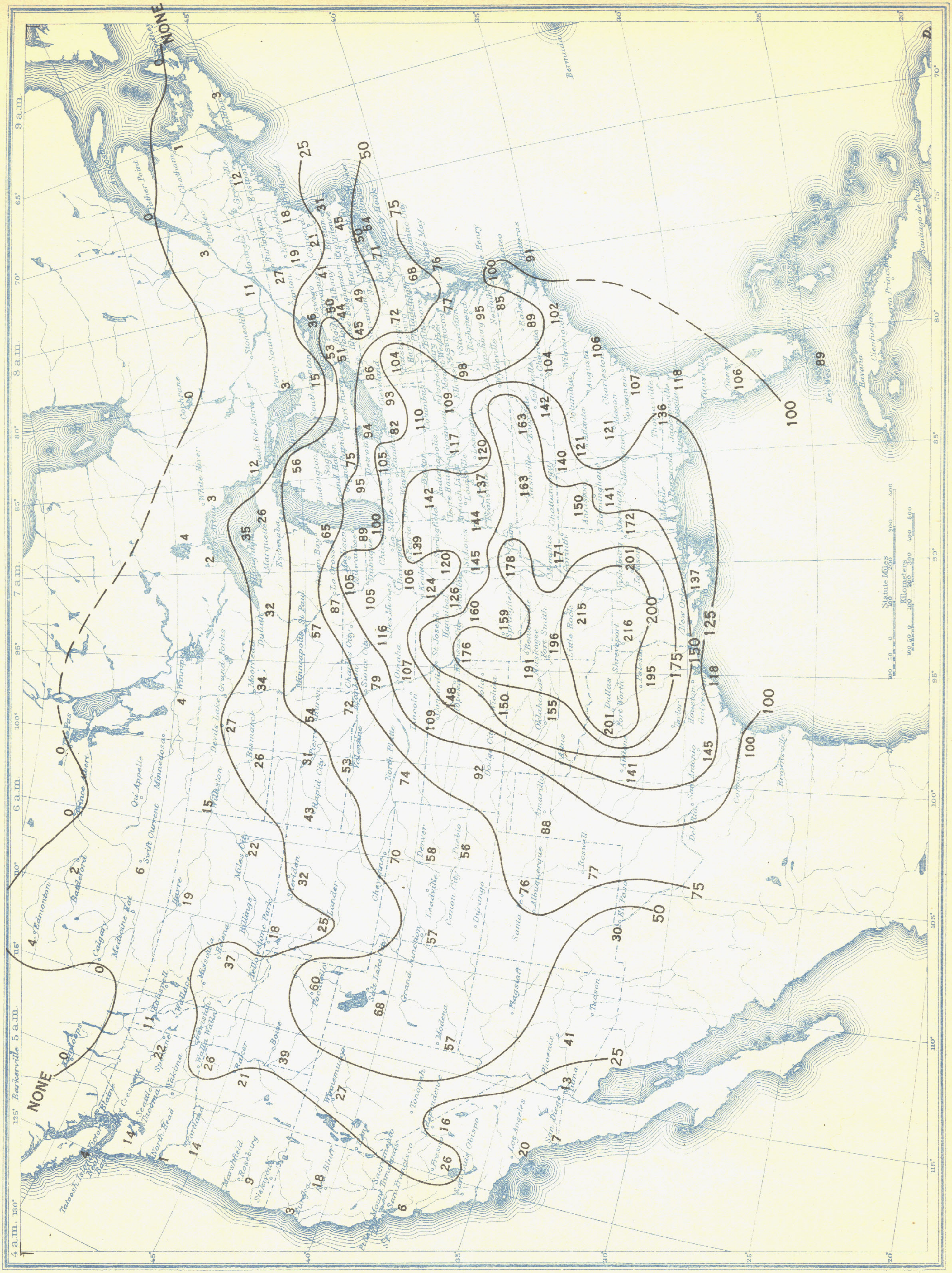
W. H. A. Figure 1.—January Isoceraunics of Total Thunderstorm Days, 1904-1933

W. H. A. **Figure 2.—February Isoceraunics of Total Thunderstorm Days, 1904-1933**



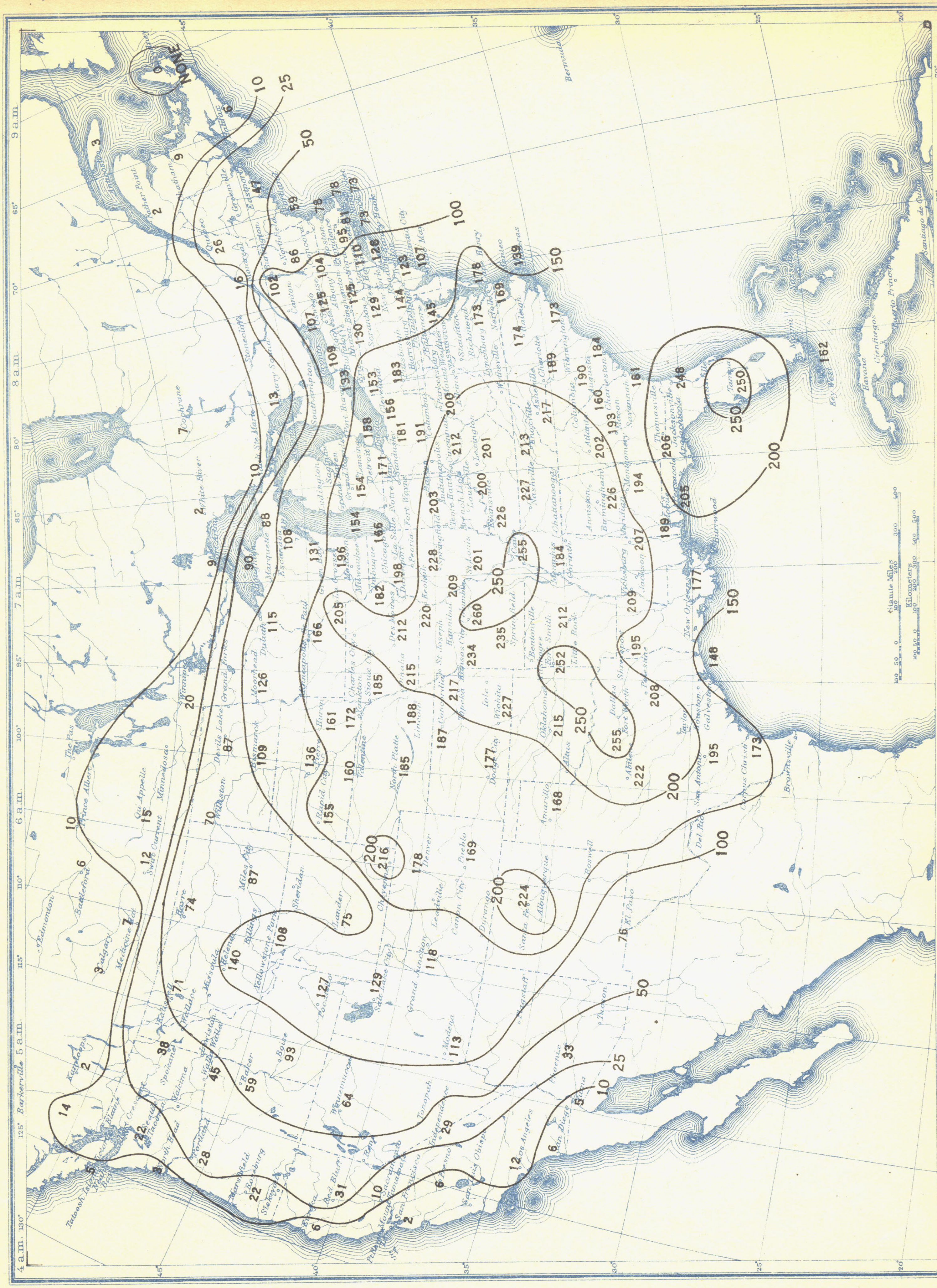


W. H. A. Figure 3.—March Isoceraunics of Total Thunderstorm Days, 1904-1933

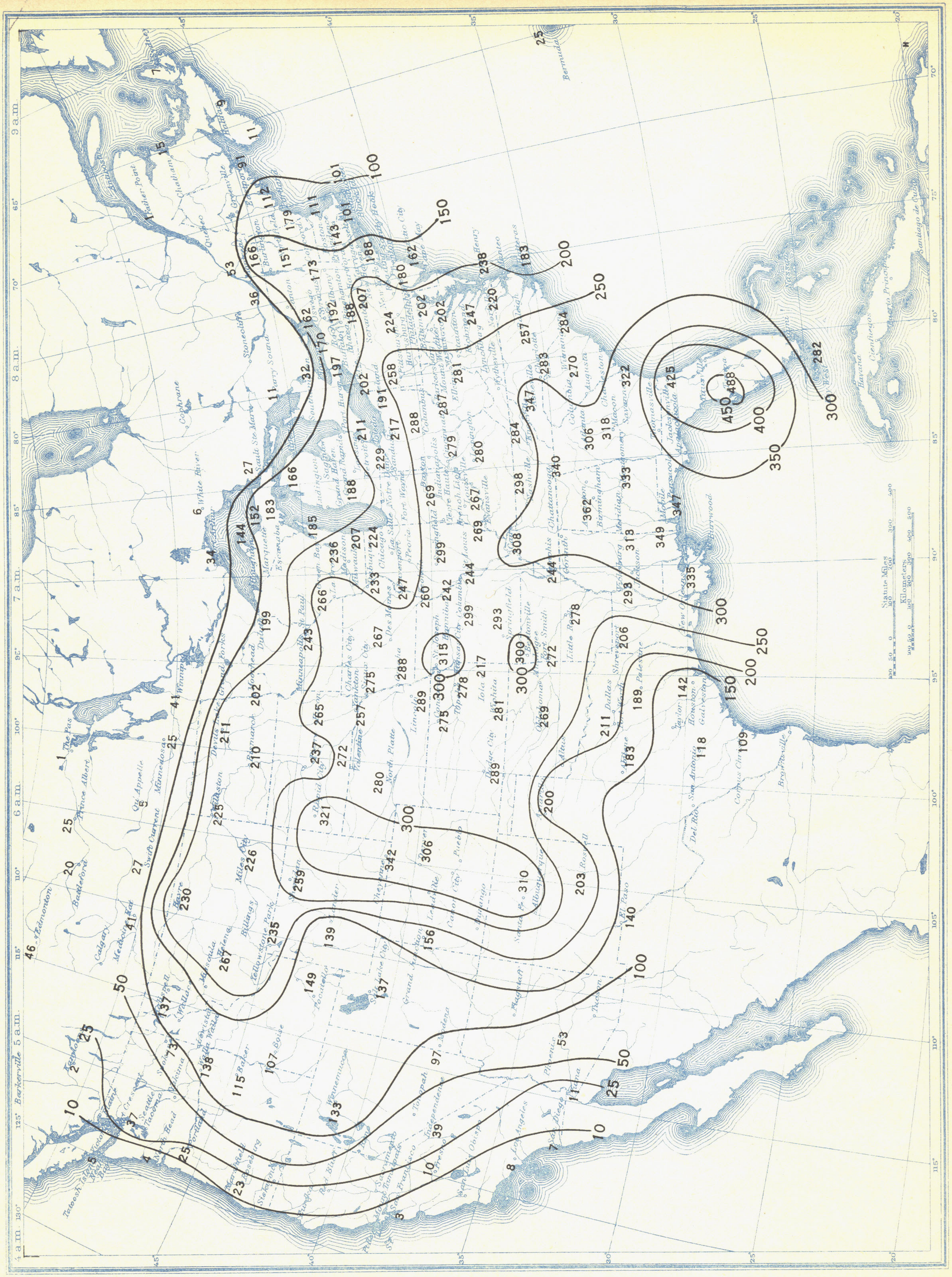


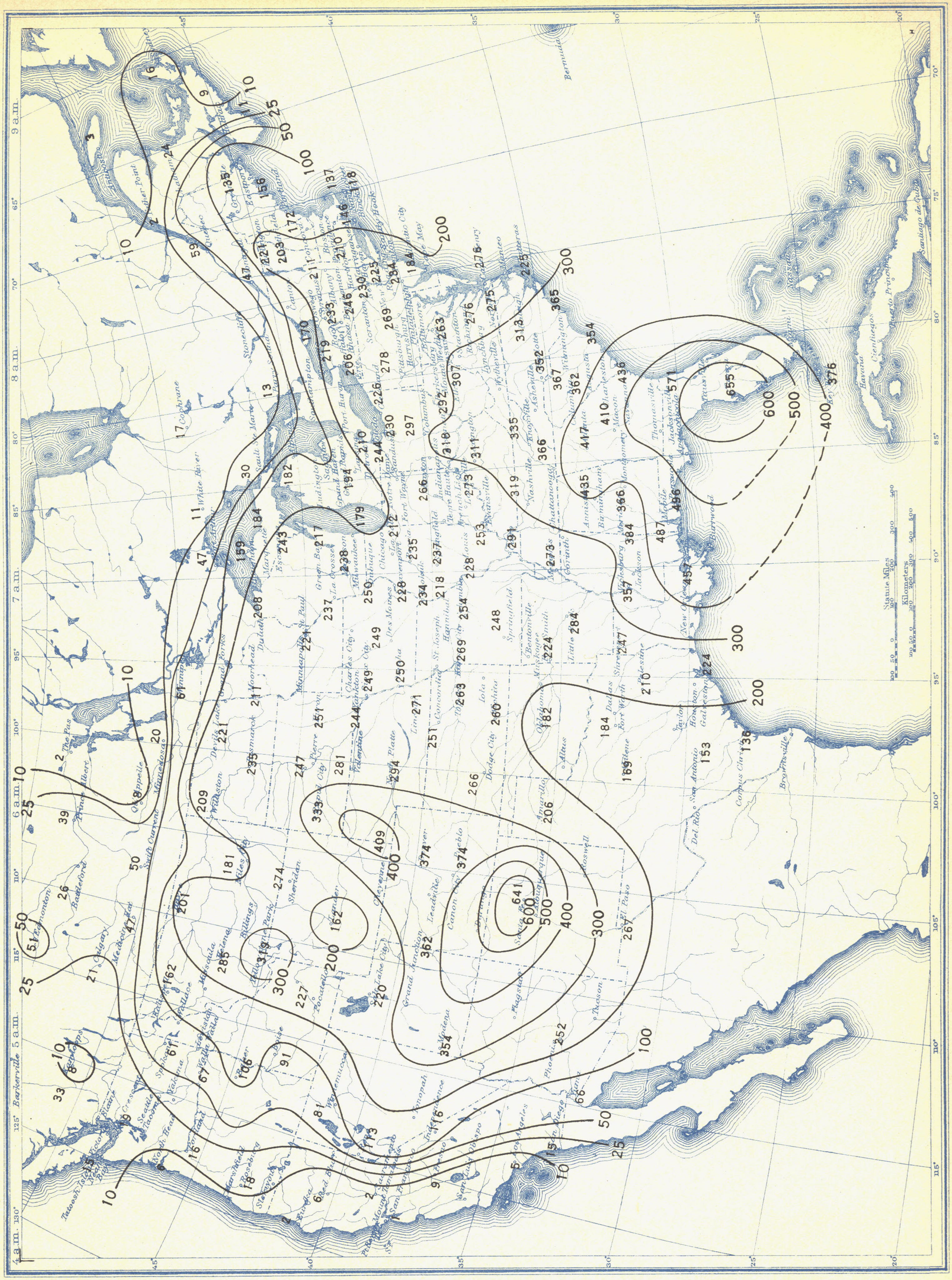
W. H. A. Figure 4.—April Isoceraunics of Total Thunderstorm Days, 1904–1933

W. H. A. Figure 5.—May Isoceraunics of Total Thunderstorm Days, 1904-1933

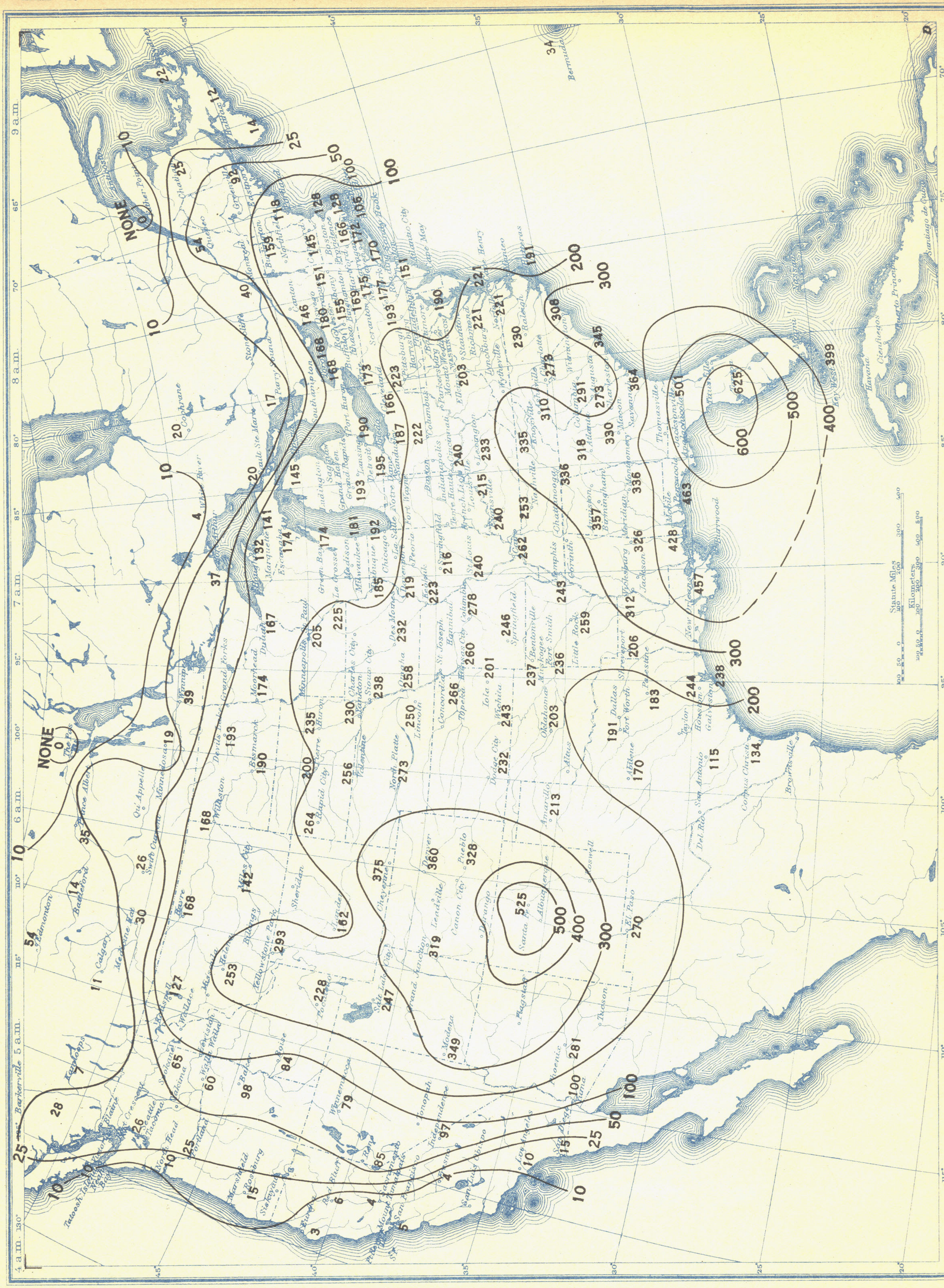


W. H. A. Figure 6.—June Isoceraunics of Total Thunderstorm Days, 1904-1933

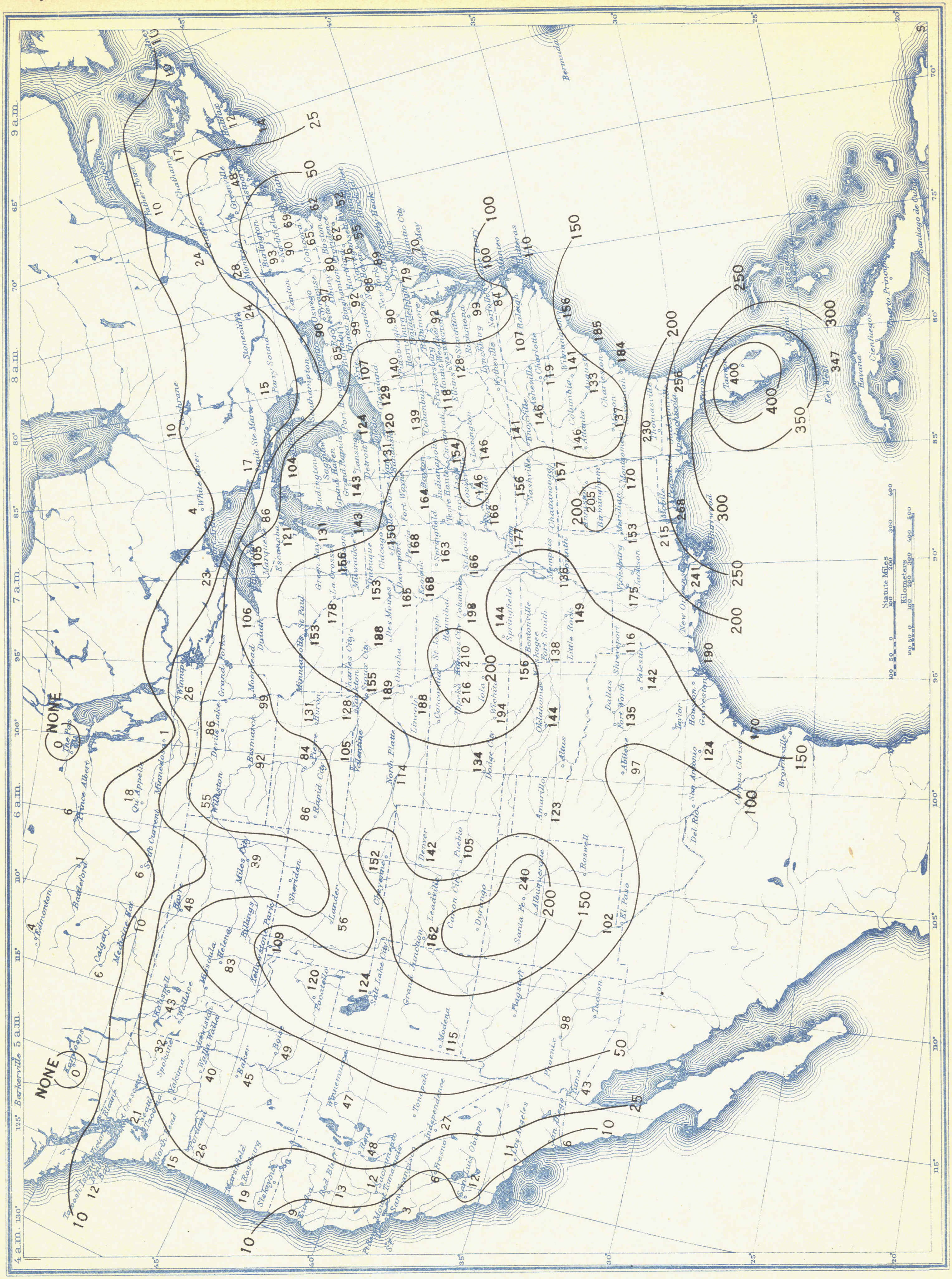




W. H. A. Figure 7.—July Isoceraunics of Total Thunderstorm Days, 1904-1933

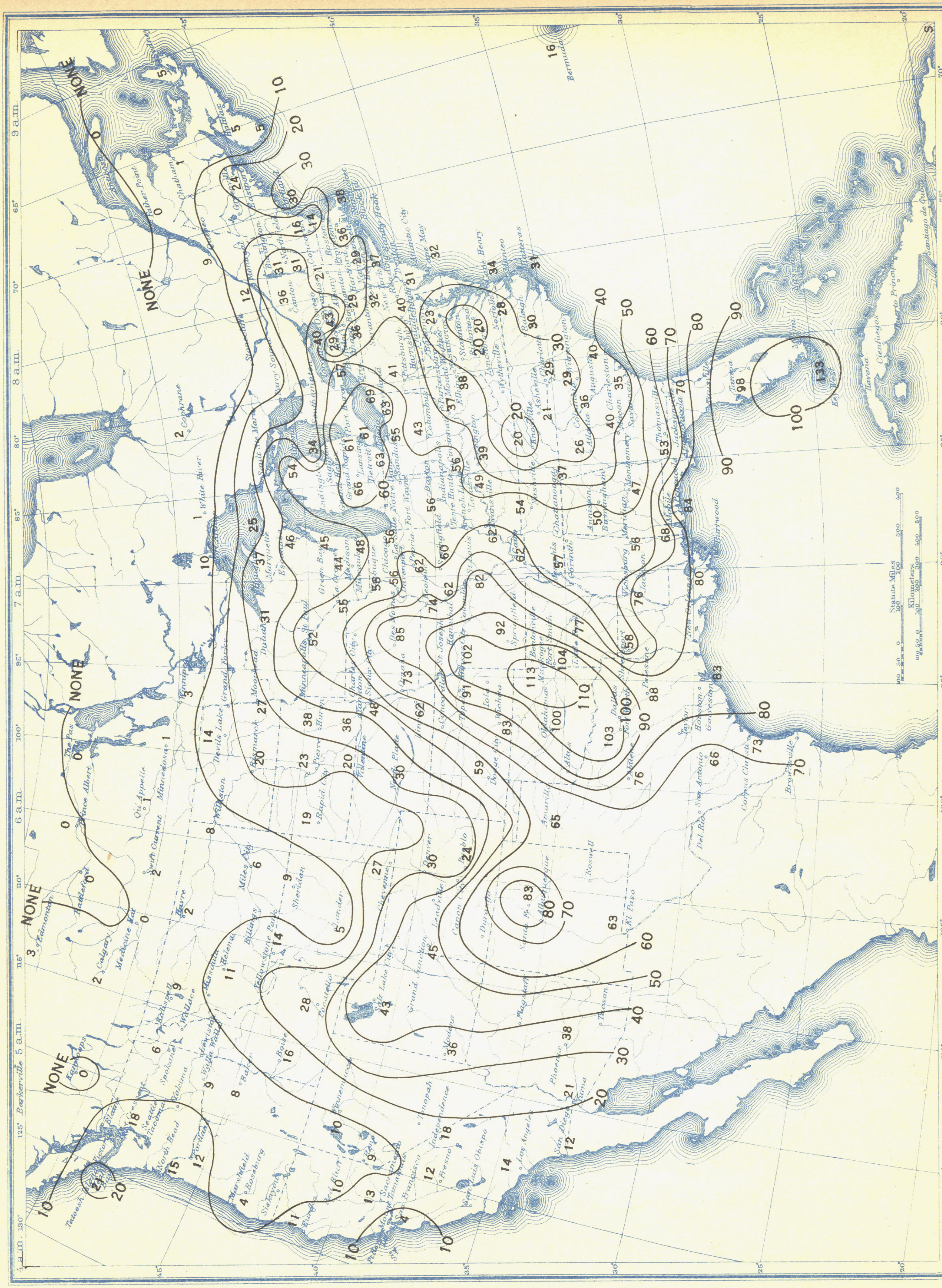


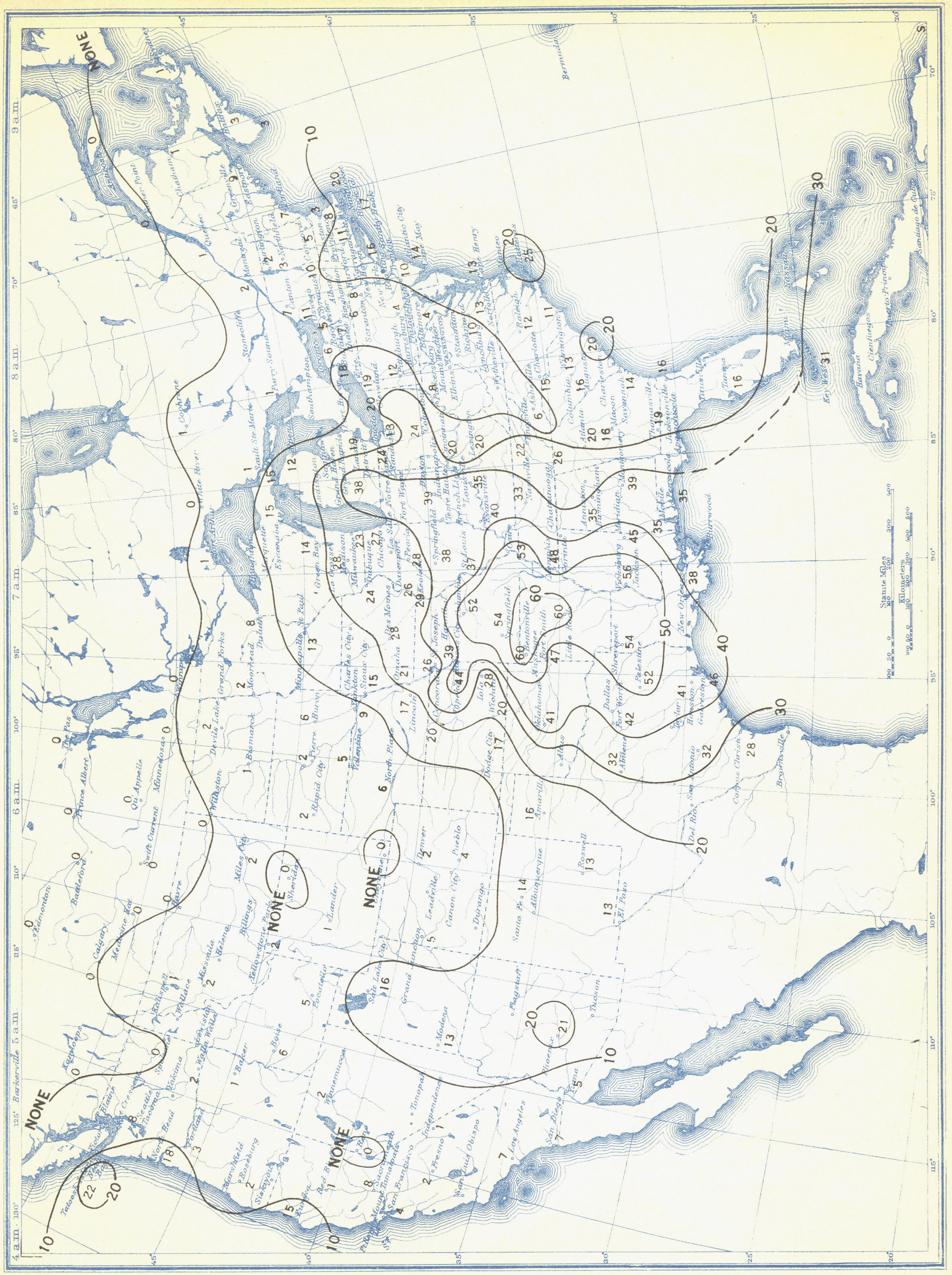
W. H. A. Figure 8.—August Isoceraunics of Total Thunderstorm Days, 1904-1933



W. H. A. Figure 9.—September Isoceraunics of Total Thunderstorm Days, 1904-1933

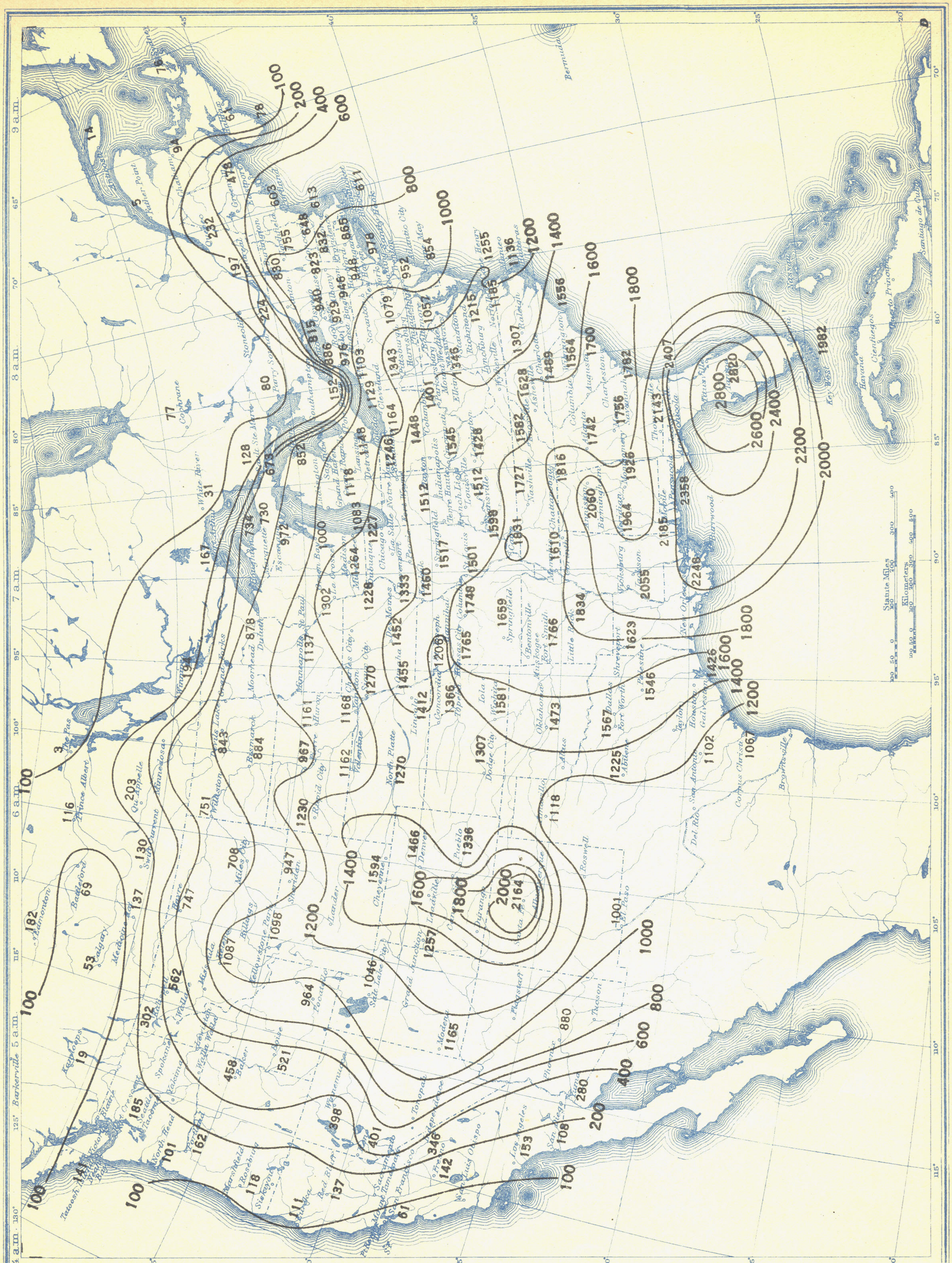
W. H. A. Figure 10.—October Isoceraunics of Total Thunderstorm Days, 1904-1933





W. H. A. Figure 11.—November Isoceraunics of Total Thunderstorm Days, 1904-1933

W. B. A. **Figure 12.—December Isoceraunics of Total Thunderstorm Days, 1904-1933**



W. H. A. Figure 13.—Annual Isoceraunics of Total Thunderstorm Days, 1904-1933